5

Role of Pulses in Sustaining Agricultural Productivity in the Rainfed Rice-Fallow Lands of India in Changing Climatic Scenario

S PANDE, M SHARMA and R GHOSH

International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Patancheru–502 324 (Andhra Pradesh), India
Email: s.pande@cgiar.org

ABSTRACT

With the growing recognition of the possibility of global climate change, an increasing emphasis on world food security in general and its regional impacts in particular have come to forefront of the scientific community. Agriculture production of rainfed regions is expected to suffer severe water crisis due to delayed monsoon, uneven distribution of rain as a result of climate change. The impact of climate change on pulses appears to be more serious. It is most unlikely that any additional area will be available for pulses cultivation in future, due to more returns with cereals under irrigation and also due to shrinking land base for agriculture. However, about 12 million hectares remains fallow during the post-rainy season after harvest of rainy season rice in the India and diverse soil types and climatic conditions of the rainfed rice fallow lands (RRFL) are suitable for growing both cool season and warm season pulses profitably during post rainy-season. The residual moisture left in the soil at the time of rice harvest will be sufficient to raise a short-season pulse crops. Further, by use of short duration and high yielding varieties of rice allowing rice to vacate fields in September-October, the traditional RRFL cropping can be converted into rice-pulses system. Inclusion of cool season and warm season pulses such as chickpea, lentil, mungbean, urdbean, fababean, lathyrus, peas etc. in RRFL will increase the productivity as well as the sustainability of the rice. This paper discusses the opportunities for the introduction of pulses and its expansion in RRFL with best bet technological interventions of crop establishment, integrated crop management and need for policy support for their use as an integral part of daily diet and a source of income to millions of resource poor farmers in the above regions.

Key words: Climate Change, Economic feasibility, Productivity, Pulses, Rainfed

1. Introduction

A lethal combination of high prices and falling supply is threatening food security. Is the climate to blame? Climate change has become a major concern to agricultural development and threatens to increase crop losses, increase in the number of people facing malnutrition, and changing the development patterns of plant diseases and insect-pests. It is well established that temperature, moisture and greenhouse gases are the major elements of climate change. Current estimates of changes in climate indicate an increase in global mean annual temperatures of 1ºC by 2025 and 3ºC by the 2100. The carbon dioxide (CO_2) concentration is rising at the rate of 1.5 to 1.8 ppm per year and is likely to be doubled by the end of 21st century (IPCC, 2007). Variability in rainfall pattern and intensity is expected to be high. Greenhouse gases (CO_2 and O_3) would result in increase in global precipitation of 2 ± 0.5ºC per 1ºC warming. Overall, changes in these elements will result in: i) warmer and more frequent hot days and nights, ii) erratic rainfall distribution pattern leading to drought or high precipitation and iii) drying of rainfed semi-arid tropics (SAT) in Asia and Africa. These changes will have major implications for food security, particularly in the developing countries, where the need to increase and sustain food production is most urgent.

Agriculture plays a key role in overall economic and social well being of India. With the growing recognition of the possibility of global climate change, an increasing emphasis on world food security in general and its regional impacts in particular have come to forefront of the scientific community. Crop growth, development, water use and yield under normal conditions are largely determined by weather during the growing season. Even with minor deviations from the normal weather, the efficiency of applied inputs and food production is seriously impaired (Rotter *et al.*, 1999). India has a major challenge to increase its food production to the tune of 300 million tones by 2020 in order to feed its growing population, which is likely to reach 1.30 billion by the year 2020. To meet the demand for food from this increased population, the country's farmers need to produce 50% more grain by 2020 (DES, 2004). The problem has become acute because urbanization and industrialization have rapidly dwindled the per capita availability of arable land from 0.48 ha in 1950 to 0.15 ha by 2000 and is likely to further reduce to 0.08 ha by 2020. The bigger question scientific community has that how can productivity be increased while ensuring the sustainability of agriculture and the environment for future generations? Decision makers need information supplied by research to make informed choices about new agricultural technologies and to devise and implement policies to enhance food production and sustainability.

Agriculture production of rainfed regions, which constitute about 65% of the area under cultivation and account for about 40-45% of the total production in India, is expected to suffer severe water crisis due to delayed monsoon, uneven distribution of rain as a result of climate change (Agarwal, 2003). The impact of climate change on pulses appears to be more serious. India's annual pulse production of 13.5 million tons (8- 27g caput^{-1} day^{-1}) is much below the requirements as per the Indian Council of Medical Research (ICMR) recommended level of consumption (50g caput^{-1} day^{-1}). Currently, India imports 2.5 to 3.5 million tones of pulses every year. In this grim scenario of demand, supply, and consumption, the pulse production needs to be doubled by 2015 in order to meet the requirement of increasing population. It can only be done by increasing area and productivity of pulses. However, it is most unlikely that any additional area will be available for pulses cultivation in future, due to more returns with cereals under irrigation and also due to shrinking land base for agriculture. However, of the 44.6 million ha of rice grown in India, about 11.7 million hectares remains fallow during the *rabi* (post-rainy season) after harvest of *kharif* (rainy season) rice. Nearly 82% of the rainfed rice fallow lands (RRFL) are located in the states of Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, and West Bengal. These RRFL offer a huge potential niche for pulses production. This paper focuses on the role of pulses in sustaining agricultural productivity in the rainfed rice fallow lands of India under the climate change scenario.

2. Pulses in Indian Agriculture

Pulses are one of the important segments of Indian agriculture after cereals. India is the largest producer of pulses in the world with the 25 % share in the global production covering an area of about 24 million hectare, majority of which falling under rainfed condition where irrigation facilities are inadequate or not available. These include chickpea, groundnut, lentil, mungbean, urdbean, fababean, lathyrus, peas etc. Pulses are predominantly grown under resource poor and harsh environments frequently prone to drought and other biotic and abiotic stresses. Pulses have excellent source of high quality protein, essential amino acids, fatty acids, mineral and vitamins for millions of Indians. In addition, pulses also play an important role in improving soil health, long term fertility and sustainability of the cropping systems. It meets up to 80% of its nitrogen fixation from air and leaves behind substantial amount of residual nitrogen and organic matter for subsequent crops (Singh *et al*., 1995). Inspite of the fact that pulses are wonderful crops among the food grains, even though they are least preferred by farmers to grow because cereals are more remunerative. Pulses are considered as a high risk crops being neglected since green revolution. As a result, the productivity of the pulses in India is quite low even less than 1 ton per hectare compared to wheat and rice (Johonson *et al.*, 2000). To meet the demand of pulses, India is presently importing about 3 million tons of pulses. To increase the pulse production to the tune of about 18 million tons from existing 15 million tons, rainfed rice fallow lands (RRFL) offer a huge potential niche for pulses production.

3. Rainfed Rice Fallow Lands-Pulses

Rainfed Rice Fallow Lands (RRFL) represent diverse soil types and climatic conditions as indicated by the GIS analysis; thus a variety of pulses such as soybean, cowpea, mungbean, black gram, chickpea, lentil, khesari, horse gram, fababean, and pea etc can be grown in these regions. Moreover, pulses have wide adaptive mechanisms such as very deep rooting system in pigeonpea and chickpea, high degree of dehydration tolerance, phenotypic plasticity, wide ranging sensitivity towards photothermoperiods and higher moisture retention capacity. The water requirement of pulses such as chickpea is about 1/5th of the requirement of cereals (Fig. 1), though response of different pulses varies towards diverse climatic conditions as per their genetic make-up.

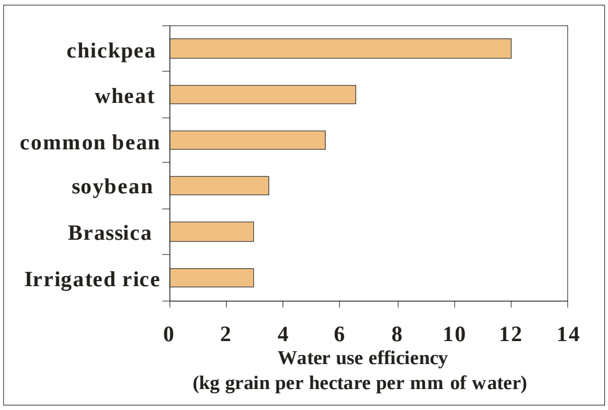

Fig. 1. Water use efficiency of pulses

There is a scope for expansion of small-seeded varieties of pulses such as lentil, lathyrus, chickpea and field pea in the *Utera* cultivation of RRFL in the states of Uttar Pradesh, Madhya Pradesh, Jharkhand, Bihar, West Bengal and Assam. The *Utera* cultivation of pulses can be made more effective by using short duration and high yielding varieties of rice, as rice will be vacating the field in September-October. In lowland areas with excessive moisture, lentil is more suitable and assured than chickpea. Consequently, the rice-lentil system can be made more popular in the lowlands of eastern Uttar Pradesh, Bihar, Jharkhand and West Bengal.

3.1 RRFL - Area

Out of 44.6 million hectare (M ha) of rice area (FAO, 2001) and based on unclassified and classified satellite images analysis, Subbarao *et al*., 2001 have estimated 11.7 M ha RRFL in the states of Bihar, Jharkhand, West Bengal, Orissa, Madhya Pradesh, Chhattisgarh, Maharashtra, and Assam in India. Nearly 4.4 M ha, accounting for one third of total RRFL in India is in Madhya Pradesh and Chhattisgarh (Fig. 2, Table 1).

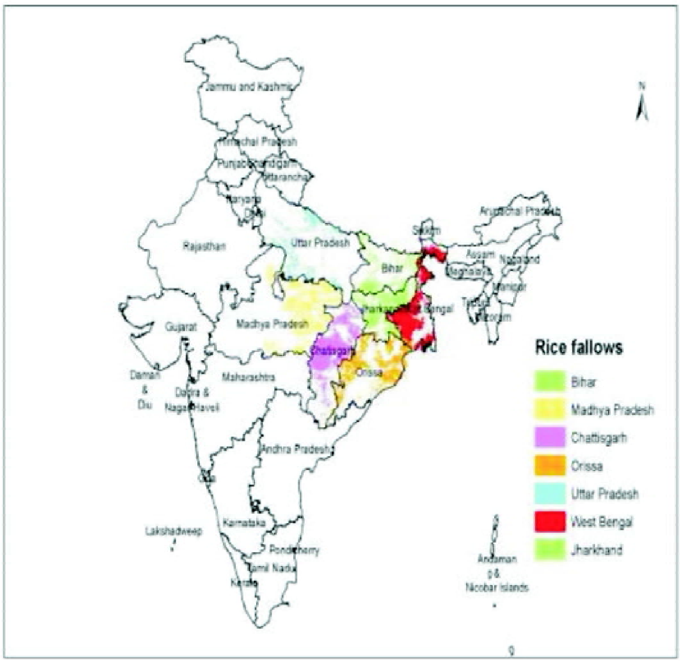

Fig. 2. Potential rainfed rice fallows for introducing pulse cultivation in central and eastern India

Table 1. Estimates of rice area during *kharif* 1999 and rainfed rice-fallows area during *rabi* 1999/2000 based on satellite image analysis for major rice-growing states in India

State	*Kharif*-rice area ('000 ha)	*Rabi*-fallow area ('000 ha)	*Rabi*-fallow area as % of *kharif* rice area	Total *rabi*-fallow area (%)
Andhra Pradesh	2657	305	11.5	2.6
Assam	2234	539	24.1	4.6
Bihar and Jharkhand	5974	2196	36.8	18.9
Gujarat	469	83	17.7	0.7
Haryana	1109	0	0.0	0.0
Karnataka	984	182	18.5	1.6
Kerala	241	0	0.0	0.0
Madhya Pradesh and Chhattisgarh	5596	4382	78.3	37.6
Maharashtra	1762	629	35.7	5.4
Orissa	3879	1219	31.4	10.5
Punjab	2498	0	0.0	0.0
Rajasthan	214	25	11.7	0.2
Tamil Nadu	1695	20	1.2	0.2
Uttar Pradesh and Uttrakhand	6255	353	5.6	3.0
West Bengal	4617	1719	37.2	14.8
Total	40184	11652	29.0	100.0

Source: Subbarao *et al.* (2001)

3.2 RRFL- Edaphic and climatic features

In India, the soils most suited to rice cultivation are heavy soils and clays or clay loams. Such soils, with high water-holding capacity, produce higher rice yields and are suitable for second crop of pulses. The most important groups of soils under which the rice is grown in India are the alluvial soils, red soils, laterite and lateritic soils, black soils, saline and alkaline soils, and peaty and marshy soils (Raychaudhuri *et al.*, 1963). Since RRFL are distributed across the country, the edaphic and climatic factors of the major RRFL states are summarized in Table 2. Available water holding capacity of 1 m soil profile of RRFL ranges from 150 mm to 200 mm, assuming that the soils in this region are fully saturated during most of the rice-growing season, the residual soil moisture at the time of rice harvest will be sufficient to raise a short-season pulse crop. Therefore, technological and policy interventions are needed to introduce and expand short duration disease resistant and high yielding varieties of pulses and rice in the RRFL and make it sustainable intensive cropping systems.

Table 2. Edaphic and climatic features of rainfed rice-fallows in India

State	Major districts	Soil type	Annual rainfall (mm)	Soil water holding capacity (mm)	Temperature	
					Max °C	Min °C
Andhra Pradesh	East Godavari, West Godavari, Krishna, Guntur, Medak, Adilabad, Rangareddy, Visakhapatnam, Viziangaram, Srikakulam	Alluvial, Chromic Vertisoils and Pellic Luvisolis	924-1392	150-200	25-30	19-23
Assam	Karimganj, Hailakandi, Cachar, Marigaon, Naogaon, Lakhimpur	Sandy and Sandy loams, Red-laom	2040-6216	200	22-28	16-22
Bihar	Aurnagabad, Gaya, Bhagalpur, Kishangang	Alluviums, red and brown	1200-1644	150-200	23-28	14-20
Chhattisgarh	RajNandgaon, Durg, Raigsrh, Raipur, Bilaspur, Raigarth, Baster	Alluvial, shallow black to medium black and mixed red-black				
Gujarat	Kheda, Vadodara, Panch Mahals, Sabar Kantha	Eutric, Cambisols, Chromic Vertisols	996-1284	100-200	29-31	18-21
Jharkhand	Palamu, Hazaribag, Lohardaga, Ranchi, Gumala, Giridih, Deoghar, Dumka, Sahibhanj, Dhanbad, Godda, Purbi Singbhum, Pashchimi Singhbhum	Alluviums, red and brown	1200-1644	150-200	23-28	14-20
Karnataka	Belgaum, Dharwad, Shimoga, Mysore	Chromic Vertisols Eutric Cambisols, Chromic Luvisols,	1392-2832	150-200	24-30	16-20
Madhya Pradesh	Shivpuri, Tikamgarh, Chhatarour, Satna, Damoh, Panna, Balaghat, Mandla, Jabalpur. Sidhi, Betul, Rewa, Shahdol	Alluvial shallow black to medium black and s Chromic vertisols	900-1200	150-200	25-29	15-21
Maharashtra	Dhule, Amaravati, Chandrapur, Bhandara, Nagapur, Nanded	Alluvium, medium and deep black	948-2688	150-200	26-30	17-22
Orissa	Kalahandi, Bolangir, Sambalpur, Sundergarh, Dhenkanal, Kheonjar, Puri, Cuttak, Baleswar, Mayurbhanj	Ferric Fluvisols, Lithosols, Dystric Nitosols, Chromic Luvisols	1140-1716	150-200	24-29	17-22
Rajasthan	Durgaour, Banswara, Chittargarh, Baran	Chromic/Luvisols,/ Chromic Vertisols	768-972	150-200	29-31	17-19
Tamil Nadu	Salem, Namakkal, Tiruchirappali, Cuddalore, Ramnathpuram, Madurai, Villupuram	Chromic Luvisols, Orthic Luvisols	1560-1800	200	27-30	21-23
Uttar Pradesh	Jalaun, Jhansi, Hamirpur, Banda, Mizapur, Sonbhadra, Kheri, Pilibhit, Agra, Mainpuri, Farrukhabad, Etawah	Eutric Cambisols, Chromic Luvisols, Ferric Luvisols, Sodic	816-1260	200	25-30	15-20
West Bengal	West Dinajpur, Maldha, Jalpaiguri, Purilia, Bankura, Medinipur, Barddhaman, Birbhum	Dystric Nitosols, Eutric Gleysols, Euritic Cambisols, Dystric Regosols	1416-2136	200	21-28	16-23

Source: Subbarao *et al.* (2001)

3.3 RRFL- Pulses and opportunities

The optimum temperature for growth and development of most tropical pulses is within the range of 25°C to 35°C, with a base temperature of 10°C (Johansen et al. 2000). On the other hand, most cool-season pulses have temperature optima for growth and development processes within the range of 15°C to 25°C, with a base temperature of 0°C (Johansen *et al.*, 1994). Some of the possible cool season and warm season pulses that can fit into RRFL are discussed below.

3.3.1 Chickpea

Chickpea is one of the major cool season grain legumes widely grown in India, and is suitable for RRFL of Uttar Pradesh, Uttarakhand, Rajasthan, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Assam, Orissa, Maharashtra, Gujarat, Andhra Pradesh, Karnataka, and Tamil Nadu. Chickpea is not a major crop in rice-based production systems in peninsular India, but has potential for expansion especially in the RRFL in Andhra Pradesh, Karnataka, Orissa, Madhya Pradesh, Chhattisgarh, Bihar and Jharkhand. In some areas of eastern and South Indian states, *Utera* cropping is practised with chickpea. There is a scope for expansion of *Utera* cultivation for pulses production in the states of Uttar Pradesh (0.055 million ha), Madhya Pradesh (0.02 million ha), Jharkhand (0.02), Bihar, West Bengal and Assam (0.005 million ha each). By use of short duration and high yielding varieties of rice, the traditional RRFL cropping can be converted into rice-chickpea system, the rice vacating the field in September-October. The additional production of chickpea from *Utera* cropping system based on average productivity of 0.3 tons ha^{-1} is expected to be 0.0165 million tons. Sequential and *Paira* cropping of RRFL is witnessing drastic changes with advances in chickpea cultivation. Development of cultivars (Uday, Pusa 372, Pusa 256 and PBG 1) coupled with suitable agronomy (sowing at high plant densities of 35-40 x 104 ha^{-1} with 30-40 kg N ha^{-1} and 2 irrigations) has led to higher productivity of late planted chickpea. This has made rice-chickpea possible in place of the existing rice-wheat system in tail end command areas of eastern Uttar Pradesh and Bihar due to increasing soil sickness. It is also becoming popular in Chhattisgarh state. Introduction of high yielding chickpea cultivars (ICCV 2 and ICCV 10) in rice fallows proved successful in Andhra Pradesh, where chickpea is replacing the traditional mung bean and urdbean crops. It is evident from the increasing area of chickpea from 0.884 lakh ha (1991) to 1.4 lakh ha (1999). Similarly, in Karnataka and Maharashtra, it is substituting rabi sorghum due to more returns. In central Madhya Pradesh, soybean-chickpea rotation is coming up in large areas, and this system has also been found economical to cotton in Guntur and Prakasham districts of Andhra Pradesh.

3.3.2 Lentil

Lentil is one of the major grain legumes grown extensively in India. Lentil is suitable for rice-fallows in Uttar Pradesh, Rajasthan, Chhattisgarh, Madhya Pradesh, Bihar, Jharkhand, Orissa, West Bengal, and Assam. Bihar and Uttar Pradesh are the major growing areas for lentil. Vast area in eastern Indo-gangetic plains is mono-cropped under medium and long duration varieties of rice. The non-availability of irrigation water and delay in vacating the field after rice do not normally permit double cropping. The topsoil layer generally dries up at the time of harvest of rice and thus, planting of a post-rainy season crop is not feasible. Under such conditions, relay cropping of small seeded lentil especially in medium deep soils could convert these mono-cropped areas into double-cropped areas and thus, increase legume production and sustain productivity of the RRFL. Expansion of this system requires development of genotypes especially suited for relay cropping and matching agro-technology, which has not received adequate attention so far.

3.3.3 Khesari or Lathyrus

Khesari is a robust legume commonly grown after rice in eastern India. It is suitable for RRFL in Uttar Pradesh, Madhya Pradesh, Bihar, Chhattisgarh West Bengal, and Assam. Khesari has wide adaptability to grow in paddy soils and it suffers much less as compared to other pulses in adverse conditions of soil moisture. It thrives best on low-lying water retentive heavy soils. Most of the Khesari is grown as a relay crop, where the seed is broadcast into the standing rice crop before its harvest (about 3 to 4 weeks). At the time of rice harvest, the Khesari crop is already established; and thus has an early advantage in establishing crop cover quickly. The improved genetic stocks such as Pusa-24, P24-1-A, Biol-212, and 24-4-A-B have negligible neurotoxin concentrations (Mehta and Santha, 1996).

3.3.4 Fababean

Faba bean is mostly cultivated in patches or as a kitchen garden crop in Uttrakhand, Uttar Pradesh, and is suitable for rice-fallows in Bihar, Uttar Pradesh, Rajasthan, Madhya Pradesh, West Bengal, and Assam.

3.3.5 Pea

Pea is adapted to a wide range of soil type’s and-environments is suitable for rice-fallows in Bihar Jharkhand, Uttrakhand, Chhattisgarh, Uttar Pradesh, northern Madhya Pradesh, West Bengal and Assam.

3.3.6 Soybean

Soybean production is mostly confined to western Uttar Pradesh and western Madhya Pradesh as a *Kharif* season crop. Soybean has a natural adaptability to grow in paddy soils, and is also tolerant to water-logging during early stages of crop growth. It is ideally suited for rice-fallows, particularly in Maharashtra and in peninsular India. Compared with other legumes in the region, soybean is less constrained by insect pests and diseases, but is more susceptible to drought stress and is less adapted to local rhizobia.

3.3.7 Greengram or Mungbean

Mungbean is mostly grown as a *kharif* crop and extensively cultivated in Bihar, Uttar Pradesh, Madhya Pradesh, and also in peninsular India. It has good adaptability to paddy soils; hence it is suitable for RRFL in Orissa, Madhya Pradesh, Chhattisgarh, Jharkhand, Bihar, Maharashtra, Andhra Pradesh, Tamil Nadu, and Karnataka.

3.3.8 Blackgram or Urdbean

Black gram is extensively grown after rice in peninsular India during the *Rabi* season. It has good adaptation to paddy soils and it is also tolerant to water logging during the early phases of crop growth. Black gram is suitable for rice-fallows in Orissa, Madhya Pradesh, Chhattisgarh, Jharkhand, Maharashtra, Andhra Pradesh, Tamil Nadu, and Karnataka during the *Rabi* season. With the availability of powdery mildew resistant cultivar, LBG 17, urdbean has been on expansion in RRFL of Andhra Pradesh. Commercialization of urdbean production in RRFL of Andhra Pradesh contributed to area expansion and higher yields from 410 kg ha^{-1} on 0.22 m ha in 1981-82 to 576 kg ha^{-1} on 0.42 m ha in 1999-2000. The other important varieties released for RRFL are LBG 402, LBG 611 and LBG 22. About 0.5 million ha additional RRFL has been brought under urdbean cultivation in Andhra Pradesh, Karnataka and Tamil Nadu since 1970-71.

3.3.9 Cowpea

Cowpea is mostly grown as a *Kharif* crop, but can be grown as a *Rabi* crop in RRFL in peninsular India. It may be suitable for RRFL in Orissa, Madhya Pradesh, Chhattisgarh, Jharkhand, Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu.

3.3.10 Horse gram

Horse gram is grown across several states of India mostly as a postrainy season crop, and is suitable for RRFL in Madhya Pradesh, Chhattisgarh, Jharkhand, Maharashtra, Orissa, Andhra Pradesh, Karnataka, and Tamil Nadu. This crop is hardy and suitable for marginal areas.

3.3.11 Lablab bean

Lablab bean is suitable for RRFL in Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, and Karnataka.

3.4 RRFL- Pulses and constraints

A number of biotic, abiotic, and socioeconomic constraints contribute to the lack of introduction of pulses in RRFL (Pande *et al.*, 2000). Among the biotic constraints, several fungal and viral diseases, insect-pests and nematodes constraint both cool season and warm season pulses production in RRFL. Among the fungal diseases, economically important soil borne diseases are wilt and root rots in chickpea, pigeonpea, lentil, and pea and foliar diseases such as chocolate leaf spot, Ascochyta blight, botrytis gray mold, rust and powdery and downy mildews in fababean, soybean, chickpea, lentil; viral diseases such as yellow mosaic in lentil, urdbean, cowpea and mungbean bean leaf roll virus in pea and sterility mosaic disease in pigeonpea. Among the insect-pests, pod borer is economically important in chickpea and pigeonpea; aphids in lentil, black gram, mungbean, cowpea and khesari. Among the nematodes, root knot nematode is economically important in chickpea, pigeonpea, soybean and *Vigna* spp. Further, due to the changes in the climate, there will be shift in the geographical distribution of insect-pests and pathogens and new diseases will emerge and minor diseases will become major (for example dry root rot in chickpea, Phytophthora blight in pigeonpea). Abiotic constraints such as water-logging during early stages of plant growth, poor plant stands, terminal drought, location specific micronutrient deficiencies (Zn, S, B, Mo), soil acidity, soil salinity/alkalinity and low soil organic matter status affect grain legumes production in RRFL.

Among the socioeconomic constraints, lack of awareness and knowledge among farmers, non-availability of adequate quantities of quality seed of improved varieties and improved crop management practices, lack of cash and credit to purchase inputs, and fragmented marketing are major constraints faced by the Indian farmers wishing to cultivate pulses in RRFL. Most of the farmers in Chhattisgarh, Madhya Pradesh, Jharkhand, Orissa and Bihar, where large areas of rice-fallows are located, are not aware of the potential economic benefits of using RRFL for pulses cultivation. In many cases, the farmers were found to have not only inadequate but also incorrect information about recommended pulse production techno1ogy (Nigam, 1980; Satyanarayana *et al*. 1988, Pande *et al*., 2009). The existing local cultivars of different pulses are not very responsive as compared to improved management practices. Credit is a key element for enabling small and marginal farmers to purchase the necessary inputs. But input mobilizing power of farmers is low because of relative high cost of technological inputs. Small land holdings make such inputs less viable. Credit facilities are not available for pulse crops in the same way that they are for other major crops such as wheat, rice, cotton, and sugarcane (Lal, 1984). Further, markets for pulses are thin and fragmented in comparison with rice and wheat. It is generally perceived that the government procurement for pulses is not as effective as it is for rice and wheat, and often, farmers do not realize the minimum prices announced by the government. Also, the price spread (i.e., the market margin) for pulses is much higher than that of rice and wheat (Joshi and Pande, 1996).

3.5 RRFL- Improved technology interventions

The research, development, and extension portfolio for introducing pulses in RRFL is farmer-driven, farmer-implemented, and farmer-owned. The researchers and technologists play a catalytic and guiding role by providing available technical options to farmers and helping them to make their appropriate choices. A review of available technology interventions indicates that it is possible to profitably cultivate pulses in identified RRFL. An economic analysis has also shown that growing pulses in RRFL is profitable with a benefit-cost ratio > 3.0. Further utilizing RRFL pulse production could result in the generation of 503 million person-days employment for India. Thus introduction of pulses with best bet interventions into RRFL will have multi-faceted impact on the sustainable livelihoods. International Crops Research Institute for the Semi-arid Tropics (ICRISAT) strongly believe that following an Integrated Genetic and Natural Resource Management (IGNRM) approach, pulses production could be enhanced in the RRFL in India. Some of the constraints and interventions for introducing pulses in RRFL are given in Table 3. We suggest below the possibilities of introducing pulses and or their improved production technology interventions in different RRFL systems to enhance their production and overall livelihood options of the farmers.

Table 3. Interventions and solutions for promotion of pulses in RRFL

Intervention	Solutions
Seed	Improved varieties
Crop establishment	Zero tillage machines
Diseases	Wilt resistance
Pod Borer	IPM responsive
Fertilizers	DAP
Micronutrients	Mb, Zn, S
Herbicides	Pendamethaline
Transfer of technology	Empowerment
Seed systems	Empowerment

3.5.1 Mechanization and crop establishment

Non-availability of equipments and seed drills for sowing pulses soon after rice harvest and capture the available soil moisture for crop establishment is the most important constraint that does not allow bringing available and suitable RRFL under legumes production. There is a need to develop, test, and modify the available seed-cum fertilizer drills to be used in the RRFL. This will overcome the problem of pulse crop establishment and generate employment at village level.

3.5.2 Location specific improved pulse production technology

Location specific improved pulse production technologies (IPPT) including the seed of short duration, improved high yielding varieties, integrated disease management (disease resistant varieties), Integrated pest management (insect-pests resistant varieties) and integrated nutrient management need to be standardized for the area and crop specific validation and scale up and scale out (Pande *et al.*, 2004, Pande *et al.*, 2000). Modem inputs such as fertilizers, pesticides, micronutrients, *etc.*, need to be advocated for more and sustainable production of pulses in the rice fallows. Simple technologies of applying phosphatic fertilizers, seed priming and pesticide seed treatment, low-cost delivery of PSB and *Rhizobium* for growing pulses to be introduced as components of IPPT to enhance soil physical properties and soil health in order to have longer term gains in pulse production. Also, another critical feature in addressing this issue is to use short-duration rice cultivars to facilitate early planting of pulses (i.e., by October) which could further improve the productivity of pulses when introduced into RRFL. Nutrient deficiency can be corrected by application of appropriate fertilizers, and this is particularly relevant for the micronutrient deficiencies that are reported to be widespread in RRFL across many regions in India (Sarkar *et al*., 1998).

3.5.3 Village level seed systems

Seed of pulses is like a biological capsule that contains full genetic information in coded form about its parentage. Therefore, maintenance of genetic purity of elite genotypes is essential to get repeated high quality performances. In self - pollinated pulses the traits can be maintained generation after generation with least efforts and resources. However, non-availability of seeds of improved varieties of pulses at village level constrains their adoption and expansion in the RRFL. Unlikely hybrid cereals and vegetable seed R&D, the private sector is least motivated in production and marketing of self pollinated seeds of pulses. Therefore, it is essential to initiate and develop farmers owned village level seed sector (for example truth labeled seed, community seed production and seeds production by farmers) in pulses.

3.5.4 Mobilization of community approach

The scattered demonstrations of the on-shelf improved technologies of pulses production in the rice fallows is affected by stray cattle and theft, thus there is a need to mobilize village and or villages as a single unit for large scale community owned demonstrations for scale-up and scale-out of location specific pulses production technologies for effective impact.

3.5.5 Location specific R & D

There is a need to shift yield frontier of pulses upwards in a wide range of environment. This calls for target-oriented and location-specific R&D efforts, which currently appears to be at a low profile. The location specific R&D needs to address the changing scenario of biotic constraint of pulses as affected by climate change.

3.5.6 Marketing

The markets for pulses are thin and fragmented, new niches need to be identified and appropriately supported by improved technologies and policies. There are numerous layers, as many as 6 to 7 levels in the marketing chain between farmers and consumers, including brokers, wholesalers, millers and retailers which make the marketing of pulses less profitable. Government should take steps to decrease the number of intermediaries between producers and consumers. There is no proper grading system for pulses in our country and grading is done by visual inspection. The absence of more stringent quality standards reflects the relatively low income and high price sensitivity of most of the consumers. Government should initiate a special quality category system to serve certain niches in the trade markets.

3.5.7 Policy support

The Government needs to provide adequate policy and institutional support to production of pulses in rice fallow areas to complement efforts of scientists in raising productivity levels in these crops. Although government regularly announces minimum support prices for pulses but their procurement is not as effective as for major cereals. So government should take measure to ensure that growers get remunerative price for their produce. Generally it is reported that the transportation cost of chickpea to surplus place/state comes out to more than the CIF/import price. It will be much more applicable when larger rice fallows will be brought under pulses production. In this context government should provide cheap transportation facilities to pulses growers. The pulses are more prone to biotic and abiotic constraints and there is no functioning policy to cover crop failure. So, in order to avoid the risks associated with legume , producers prefers cultivation of cereals even if in some cases, there is greater profitability over cereals.

3.6 RRFL– Pulses: Strategy and approach

The IPPT strategy is science-based farmer centric participatory research and development approach through empowerment of farmers. We have standardized the main elements of the strategy and approach for introduction of pulses specifically chickpea in RRFL (Pande *et al.*, 2010). Sowing of chickpea and crop establishment in RRFL depends upon the termination of monsoons. Normally rains continue up to the end of September and chickpea can be sown as follows:

Unirrigated early sown: Third week of September to Second week of October

Unirrigated/partially irrigated timely sown: Last week of October- Second week of November

Irrigated late sown: First week of December

There is an ample scope for the expansion of high yielding, short duration pest and drought tolerant varieties in chickpea [for example JG 74, JG 130, KPG 59, JG 315, ICCV 10, JG 11, Vaibhav and Shweta (ICCV 2), ICCC 37, Vijay, JGK 1 (Kabuli), JGK 2 (Kabuli) responsive to IPPT in the RRFL to make chickpea production more economical and sustainable. These varieties have been developed both by ICAR, SAUs and ICRISAT. The IPPT includes minimal/ zero tillage for crop establishment (ZT), integrated diseases management (IDM), integrated pest management (IPM) and integrated nutrient management (INM). These improved short-duration chickpea varieties were found suitable in rotation with recently introduced short duration high yielding rice varieties such as Hybrid (JRH-5), JR-201, MTU 1010 and Purnima. Strategy and approach followed to introduce and expand chickpea in RRFL of Chhattisgarh and Madhya Pradesh is as follows:

3.6.1 Selection of sites and farmers

Based on the previously remotely sensed data and identified rainy season fallows, in consultation with the target group and in partnership with SAU's and associated NGOs, farmers initially selected in phased manner in target villages identified in blocks in respective districts in the target state for IPPT interventions (Figure 3).

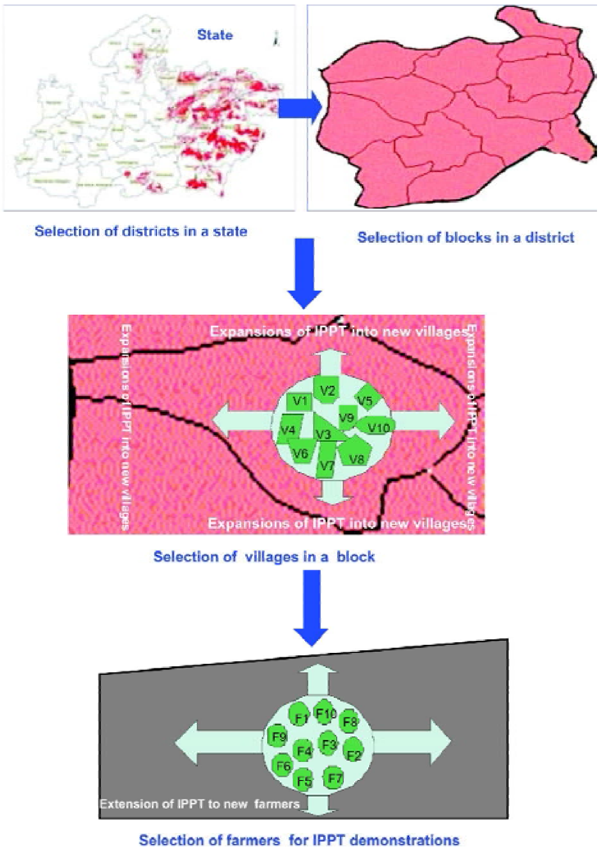

Fig. 3. Model followed for selection of farmers in village/ block/district/state for introduction of chickpea in Madhya Pradesh and Chhattisgarh

3.6.2 Soil sampling and chemical analysis

Representative soil samples from the target villages collected and analysed for micro and other essential nutrient deficiency. This exercise will help in the application of soil analysis based application of fertilizers and micronutrients at target villages.

3.6.3 Establish IPPT demonstrations

In each village, farmers' participation is sought to establish demonstration cum sites of learning and transfer of technology on IPPT for candidate crops. To establish chickpea and other crops on time in the rice fallows without loosing the soil moisture, locally available bullock drawn seed cum fertilizer drills suitable for rice fallows used. This will overcome the problem of chickpea and other crop establishment and generate employment at village level.

3.6. 4 Village level seed production

The pilot farmers also trained as seed producers, and individual and village seed storage banks [1-2 in each village] established to ensure quality supply of seeds in the pilot villages and for further expansion of chickpea and other suitable crops production in RRFL.

3.6.5 Establish sites of learning

Established 2-3 villages in each of the pilot blocks and district as sites of learning for enhancing pulse productivity by cultivating rainy season fallow lands with ICPT.

3.6.6 IPPT-orientation camps

Just before the crop season IPPT-orientation camps organized in each village or cluster of villages where farmers were explained the components of IPPT such as :

1. Improved varieties of chickpea and other crops,
2. Crop establishment using locally available seed drills and or local practices,
3. Initiation of IPM, IDM, and INM capacity building camps,
4. Initiation and establishment of village level Seed production and Storage System for successful implementation of participatory ICPT- demonstrations.

3.6.7 Monitoring and hands on training

Participatory monitoring of IPPT trials during the critical crop stages organized in each village to identify and share the observations, constraints and perception of the pilot farmers with non participating farmers, farmers from the non-pilot villages and districts encouraged to participate in such crop monitoring and discussions.

3.6.8 Backstop research

Backstop research on the identified biotic/abiotic constraints for example diseases of chickpea (dry root rot, collar rot) and drought resistant cultivars of chickpea initiated to support the project identified activities. Biology and epidemiology of the diseases studied in detail for further research on the emerging diseases.

3.7 RRFL- Pulses and Economic Feasibility

Investigations to grow pulses in RRFL showed that their cultivation is not only agronomically feasible but it is economically viable as well. About 11.65 mha RRFL in India can be expanded for pulses through diversification of rice-wheat, maize- wheat and rice-rice cropping system by substituting wheat/rice with pulses. Establishment of a sustainable seed production and delivery system at the village level will facilitate the spread of new farmer-preferred pulses varieties to 60-80% of the crop area in targeted villages and nearby areas. The seed cost will also come down as it will be produced where it is needed most, thus eliminating transport costs and middlemen. The integrity and quality of the seed would be assured as it would be produced by trained farmers. As a result, returns to investment in research will increase and its benefits will be more equitably distributed. Adoption of improved varieties will lead to increased crop productivity by 20-30% leading to higher incomes to resource poor farmers in the region. This will have direct impact in alleviating rural poverty. In a labor surplus economy like India, scope for employment generation is always an opportunity for the farm households and the national economy. On an average, cultivation of legumes in one hectare of RRFL would generate more than 43 person-days working opportunity and more than Rs. 2,500 remuneration as labor wage (Subbarao *et al.*, 2001). If all the RRFL (11.65 million ha) can be brought under pulses cultivation then additional employment creation in Indian agriculture will be 502.7 million person-days.

4. Conclusion

Most pronounced effect of climate change is a drastic change in the rainfall pattern, delayed monsoon or inadequate precipitation leading to conversion of some parts drier and vulnerable, particularly in rainfed ecosystem. Pulses are mostly cultivated under theses rainfed regions which are severely threatened by recurrent drought events. No precise weather prediction models are available so-far for onset of monsoon rainfall in India. Pulses are obviously at higher risk. Therefore, we must intensify research on assembling genetic material for a warming period, developing short duration pulses fitting into different cropping system. RRFL offer some of the most productive lands for pulse production; if suitably integrated it can revolutionize pulse production, and thus per capita availability of pulses in India. Adequate policy support from the government is necessary for support price, strengthening of extension agencies, and also by providing the needed inputs and credits to the farmers to encourage pulse production.

References

Aggarwal PK, 2003. Impact of climate change on Indian agriculture. Journal of Plant Biology 30(2): 189–198.

DES, 2004. Agricultural Statistics at a glance, Directorate of Economics and Statistics, Government of India, New Delhi, pp. 221.

FAO (Food and Agriculture Organization of the United States), 2001. Website: http://www.fao.org.

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 996.

Johansen C, Ali M, Gowda CLL, Ramakrishna A, Nigam SN and Chauhan YS, 2000. Regional opportunities for warm season grain legumes in the Indo-Gangetic Plain. Pages 185-199 in Legumes in rice and wheat cropping systems of the Indo-Gangetic Plain -Constraints and opportunities (Johansen C, Duxbury JM, Virmani SM, Gowda CLL, Pande S and Joshi PK, eds). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics; and Ithaca, New York, USA: Cornell University.

Johansen C, Baldev B, Brouwer JB, Erskine W, Jermyn WA, Lijuan L, Malik BA, Miah AA and Silim JN, 1994. Biotic and abiotic stresses constraining productivity of cool season pulses in Asia, Africa and Oceania. Pages 175-193 in Expanding the production and use of cool season pulses (Muehlbauer PJ and Kaiser WJ, eds). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Joshi PK and Pande S, 1996. Constraints to and prospectus of extra-short-duration pigeonpea in northern India: Some socioeconomic aspects. Pages 106-115 in Prospectus for growing extra-short-duration pigeonpea in rotation with other winter crops: Proceedings of the IARI-ICRISAT Workshop and Monitoring Tour, 16-18 October 1995, New Delhi, India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Lal S, 1984. Constraints and opportunities in pulse production in eastern Uttar Pradesh. Pages 89-106 *in* Pulse production constraints and opportunities (Srivastava HC, Bhaskaran S, Menon KKG, Ramanujam S and Rao MV, eds). New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd.

Mehata SL and Santha IM, 1996. Plant biotechnology for development of non-toxic strains of *Lathyrus sativus.* Pages 129-138 *in Lathyrus* genetic resources in Asia. Proceedings of a Regional workshop, 27-29 December 1995, Raipur, India. New Delhi, India: International Plant Genetic Resources Institute (IPGRI) Office for South Asia.

Nigam RK, 1980. Knowledge level of farmers on improved pulse production. Indian Journal of Pulses Research 3: 100-101.

Pande S, M Sharma, Rao SK and Sharma RN, 2010. Annual Progress report 2009-10. Collaborative work on "Enhancing chickpea production in rainfed rice fallow lands (RRFL) of Chhattisgarh and Madhya Pradesh states of India following Improved Pulse Production and Protection Technologies (IPPPT)". International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, CG and Jawharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, MP.

Pande S, Verma A, Rao SK, Pandey RL, Urkurkar JS, and Gowda CLL, 2009. Mechanizing rice fallows for self sufficiency in pulses production. [Abstract] Pages 293-294 Innovations for improving efficiency, equity and environment. 4th World Congress on Conservation Agriculture 4-7 February 2009, New Delhi, India.

Pande S, Masood Ali, Gupta RK and Kishore GK, 2004. Pest Management in Pulses Under Rice-Wheat Crop Diversification. Pages 444-456 in "Pulses in New Perspective" (Masood Ali, Singh BB, Shiv Kumar and Vishwa Dhar, eds). Indian Society of Pulses Research and Development, IIPR, Kanpur, India.

Pande S, Sharma SB and Rama Krishna A. 2000. Biotic Stresses affecting legumes production in the Indo Gangetic Plains. Pages 129-155 in Legumes in Rice-Wheat cropping systems of the Indo Gangetic Plains - Constraints and Opportunities. Patancheru 502 324, Andhra Pradesh, India (Johansen C, Duxbury JM, Virmani SM, Gowda CLL, Pande **S** and Joshi PK, eds.). International Crops Research Institute for the Semi-Arid Tropics; and New York, Cornell University.

Raychaudhutri SP, Agarwal RR, Datta Biswas NR, Gupta SP and Thomas PK, 1963, Soils of India. New Delhi, India: Indian Council of Agricultural Research.

Rotter R and Van de Geijn SC, 1999. 'Climate change effects on plant growth, crop yield and livestock'. Climate Change 43(4): 651–681.

Sarkar AK, Lal S, Singh RP and Singh S, 1998. Soils of Bihar plateau -Their characteristics and management. Technical Bulletin No. 3/98, Department of Soil Science & Agricultural Chemistry, Ranchi, India: Birsa Agricultural University.

Satyanarayana A, Murthy SS, Johansen C, Laxman Singh, Chauhan YS and Kumar Rao JVDK, 1988. Introducing pigeonpea into rice-fallows of coastal Andhra Pradesh. International Pigeonpea Newsletter 7: 11-12.

Singh DP, 1995. Pulses in India. Pages 101-112 *in* Production of pulse crops in Asia and the Pacific region (Sinha SK and Paroda RS, eds). Bangkok, Thailand: Regional Office for Asia and the Pacific (RAPA), Food and Agriculture Organization of the United Nations.

Subbarao GV, Kumar Rao JVDK, Kumar J, Johansen C, Deb UK, Ahmed I, Krishna Rao MV, Venkataratnam L, Hebber KR, Sai MVSR and Harris D, 2001. Spatial distribution and quantification of rice-fallows in South asis-potential for legumes. Patancheru 502324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, pp. 316.